Nano-injector Photo-transistor

Naval Research Laboratory nrl.navy.mil

At a Glance

What is it?

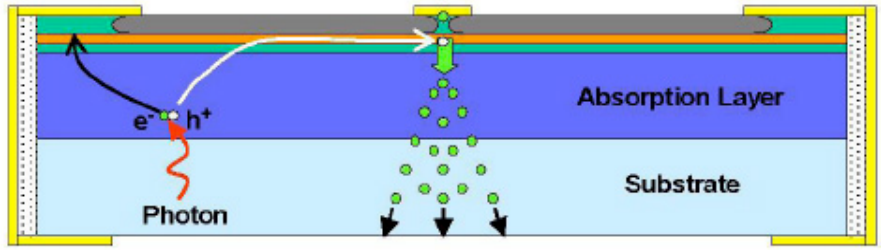
NRL is developing infrared (IR) nano-injector phototransistor (IR-NIPT) technology, for high-gain active IR-sensors that operate at low bias and are compatible with passive read-out integrated circuits (ROICs).

How does it work?

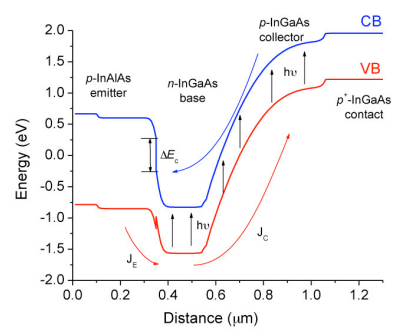
In the IR-NIPT, a large area collector is coupled to a much smaller base and emitter regions. Short wave IR (SWIR) photons create minority electrons in the collector, which are swept into the base by the negative emitter-collector bias. The injection of photo-electrons into the small-volume base region is accompanied by transistor base-collector current gain, magnified by the large collector to base-emitter volume ratio. The resulting high photo-current gain is produced without avalanche multiplication, avoiding high operating bias and the potential for high excess noise.

What will it accomplish?

NIPT-based active IR sensor with high gain at low operating bias will enable the production of active imaging arrays using state-of-the-art passive ROIC designs, instead of requiring specialized ROICs capable of providing large operating biases.



NRL is developing infrared (IR) nano-injector phototransistor (IR_NIPT) technology, for high-gain, low excess-noise factor active IR-sensors that operate at a bias of only about one volt. The low operating bias, high gain sensor would enable the production of active imaging arrays using passive read-out integrated circuit (ROIC) designs. In the IR NIPT architecture, a thick, large are, lightly p-type collector is coupled to a much smaller and thinner base and emitter regions. Short wave IR (SWIR) photons are absorbed in the InGaAs collector, and minority electrons diffuse and are then swept into the base by the negative emitter-collector bias that initially drops mainly across the collector base junction, on the much more lightly p-doped collector side. The injection of photo-electrons into the small-volume base region then slightly forward biases the emitter-base junction, creating photocurrent. The high photocurrent gain is analogous to the well-known base-collector current gain factor of bipolar transistors. The p-type emitter is comprised of a wider-gap material such as INAIAs in order to suppress minority-carrier injection into the emitter and mitigate surface effects on the exposed emitter-base sidewalls. A large collector to base-emitter volume ratio which is designed to be on the order of 1000 is used to obtain large emitter current densities and high gains even at low light levels.



The two major benefits of this approach are that it produces high gain (~5000) at low bias, and does so without using avalanche multiplication to provide low excess-noise factor, that would otherwise wipe out the benefits of high gain. NIPT-based active IR sensors with high gain at low operating bias will enable the production of active imaging arrays using standard ROIC designs, instead of requiring specialized ROICs capable of providing 10-50 V biases typically required for avalanche photodiode detectors (APD's). Thus active imagers could be made with the same state-of-the-art array size and pixel pitch as passive systems, and could be readily substituted for them as applications demand.

Research Challenges and Opportunities

- Optimizing the NIPT bandstructure and collector-base volume ratio to provide high gain at low bias.
- Fabrication of the nano-injector structure and passivation of the emitter-base mesa and exposed collector surface